

Catching Fire

How Cooking Made Us Human

RICHARD WRANGHAM

BASIC BOOKS

A MEMBER OF THE PERSEUS BOOKS GROUP
New York

Copyright © 2009 by Richard Wrangham

Hardcover first published in 2009 by Basic Books,
A Member of the Perseus Books Group
Paperback first published in 2010 by Basic Books

All rights reserved. Printed in the United States of America.
No part of this book may be reproduced in any manner
whatsoever without written permission except in the case of
brief quotations embodied in critical articles and reviews. For
information, address Basic Books, 387 Park Avenue South,
New York, NY 10016-8810.

Books published by Basic Books are available at special
discounts for bulk purchases in the United States by
corporations, institutions, and other organizations. For more
information, please contact the Special Markets Department at
the Perseus Books Group, 2300 Chestnut Street, Suite 200,
Philadelphia, PA 19103, or call (800) 810-4145, ext. 5000, or
e-mail special.markets@perseusbooks.com.

Designed by Timm Bryson
Set in 11 point Minion by the Perseus Books Group

The Library of Congress has cataloged the hardcover as follows:
Wrangham, Richard W., 1948—

Catching fire : how cooking made us human / Richard
Wrangham.
p. cm.

Includes bibliographical references.

ISBN 978-0-465-01362-3 (alk. paper)

1. Prehistoric peoples—Food. 2. Roasting (Cookery)—
History. 3. Fire—History. 4. Hearths, Prehistoric. 5. Food
habits—History. I. Title.

GN799.F6W73 2009
394.1'2—dc22

2009001742

Paperback ISBN: 978-0-465-02041-6

10 9 8 7 6 5 4

The Cook's Body

"Domestication of fire probably reacted on man's physical development as well as on his culture, for it would have reduced some selective pressures and increased others. As cooked food replaced a diet consisting entirely of raw meat and fresh vegetable matter, the whole pattern of mastication, digestion, and nutrition was altered."

—KENNETH OAKLEY, *Social Life of Early Man*

Although humans fare poorly on raw diets nowadays, at some time our ancestors must have utilized bush fruits, fresh greens, raw meat, and other natural products as efficiently as apes do. What can account for the change? Why, given all the obvious advantages of being able to extract large amounts of energy from raw food, have humans lost this ancient ability?

In theory an evolutionary mishap might be responsible for this failure of our biology: the genetic coding for a well-adapted digestive system could have been lost by chance. But a failure of evolutionary adaptation is an unlikely explanation

for something as widespread and labor-intensive as cooking. Natural selection mostly generates exquisitely successful designs, particularly for features that are as important and in such regular use as our intestinal systems. We can expect to find a compensatory benefit that has been made possible by our inability to utilize raw food effectively.

Evolutionary trade-offs are common. Compared to chimpanzees, we climb badly but we walk well. Our awkwardness in trees is due partly to our having long legs and flat feet, but those same legs and feet enable us to walk more efficiently than other apes. In a similar way, our limited effectiveness at digesting raw food is due to our having relatively small digestive systems compared to those of our cousin apes. But the reduced size of our digestive systems, it seems, enables us to process cooked food with exceptional proficiency.

We can think of cooked food offering two kinds of advantage, depending on whether species have adapted to a cooked diet. Spontaneous benefits are experienced by almost any species, regardless of its evolutionary history, because cooked food is easier to digest than raw food. Domestic animals such as calves, lambs, and piglets grow faster when their food is cooked, and cows produce more fat in their milk and more milk per day when eating cooked rather than raw seeds. A similar effect appears in fish farms. Salmon grow better on a diet of cooked rather than raw fishmeal. No wonder farmers like to give cooked mash or swill to their livestock. Cooked food promotes efficient growth.

The spontaneous benefits of cooked food explain why domesticated pets easily become fat: their food is cooked, such as the commercially produced kibbles, pellets, and nuggets given to dogs and cats. Owners of obese pets who recognize this connection and see cooked food as a health threat sometimes choose to feed raw food to their beloved ones to help them lose weight. Biologically Appropriate Raw Food, or BARF, is a special diet advertised as being beneficial for dogs for the same reason that raw-foodists advocate raw diets for humans: it is natural. "Every living animal on earth requires a biologically appropriate diet. And if you think about it, not one animal on earth is adapted by evolution to eat a cooked food diet. This means the BARF diet is exactly what we should be feeding our pets." The effects of this diet is reminiscent of raw-foodists' experience: "You can always tell a raw-food dog; they look better, have more energy, are thin and vibrant," says an owner of a golden retriever whose coat started glowing within a week of eating raw food exclusively.

Even insects appear to get the spontaneous benefits of cooked food. Researchers rearing agricultural pests in large numbers to find out how to control them give each insect species its own particular recipe of cooked food. Larvae of the diamondback moth thrive on a toasted mix of wheat germ, casein, bean meal, and cabbage flour. Black vine weevils do best on thoroughly boiled and blended lima beans. Whether domestic or wild, mammal or insect, useful or

pest, animals adapted to raw diets tend to fare better on cooked food.

In humans, because we have adapted to cooked food, its spontaneous advantages are complemented by evolutionary benefits. The evolutionary benefits stem from the fact that digestion is a costly process that can account for a high proportion of an individual's energy budget—often as much as locomotion does. After our ancestors started eating cooked food every day, natural selection favored those with small guts, because they were able to digest their food well, but at a lower cost than before. The result was increased energetic efficiency.

Evolutionary benefits of adapting to cooked food are evident from comparing human digestive systems with those of chimpanzees and other apes. The main differences all involve humans having relatively small features. We have small mouths, weak jaws, small teeth, small stomachs, small colons, and small guts overall. In the past, the unusual size of these body parts has mostly been attributed to the evolutionary effects of our eating meat, but the design of the human digestive system is better explained as an adaptation to eating cooked food than it is to eating raw meat.

Mick Jagger's biggest yawn is nothing compared to a chimpanzee's. Given that the mouth is the entry to the gut, humans have an astonishingly tiny opening for such a large species. All great apes have a prominent snout and a wide grin: chim-

panzees can open their mouths twice as far as humans, as they regularly do when eating. If a playful chimpanzee ever kisses you, you will never forget this point. To find a primate with as relatively small an aperture as that of humans, you have to go to a diminutive species, such as a squirrel monkey, weighing less than 1.4 kilograms (3 pounds). In addition to having a small gape, our mouths have a relatively small volume—about the same size as chimpanzee mouths, even though we weigh some 50 percent more than they do. Zoologists often try to capture the essence of our species with such phrases as the naked, bipedal, or big-brained ape. They could equally well call us the small-mouthed ape.

The difference in mouth size is even more obvious when we take the lips into account. The amount of food a chimpanzee can hold in its mouth far exceeds what humans can do because, in addition to their wide gape and big mouths, chimpanzees have enormous and very muscular lips. When eating juicy foods like fruits or meat, chimpanzees use their lips to hold a large wad of food in the outer part of their mouths and squeeze it hard against their teeth, which they may do repeatedly for many minutes before swallowing. The strong lips are probably an adaptation for eating fruits, because fruit bats have similarly large and muscular lips that they use in the same way to squeeze fruit wads against their teeth. Humans have relatively tiny lips, appropriate for a small amount of food in the mouth at one time.

Our second digestive specialization is having weaker jaws. You can feel for yourself that our chewing muscles, the

temporalis and masseter, are small. In nonhuman apes these muscles often reach all the way from the jaw to the top of the skull, where they sometimes attach to a ridge of bone called the sagittal crest, whose only function is to accommodate the jaw muscles. In humans, by contrast, our jaw muscles normally reach barely halfway up the side of our heads. If you clench and unclench your teeth and feel the side of your head, you have a good chance of being able to prove to yourself that you are not a gorilla: your temporalis muscle likely stops near the top of your ear. We also have diminutive muscle fibers in our jaws, one-eighth the size of those in macaques. The cause of our weak jaws is a human-specific mutation in a gene responsible for producing the muscle protein myosin. Sometime around two and a half million years ago this gene, called MYH16, is thought to have spread throughout our ancestors and left our lineage with muscles that have subsequently been uniquely weak. Our small, weak jaw muscles are not adapted for chewing tough raw food, but they work well for soft, cooked food.

Human chewing teeth, or molars, also are small—the smallest of any primate species in relation to body size. Again, the predictable physical changes in food that are associated with cooking account readily for our weak chewing and small teeth. Even without genetic evolution, animals reared experimentally on soft diets develop smaller jaws and teeth. The reduction in tooth size produces a well-adapted system: physical anthropologist Peter Lucas has calculated

that the size of a tooth needed to make a crack in a cooked potato is 56 percent to 82 percent smaller than needed for a raw potato.

Continuing farther into the body, our stomachs again are comparatively small. In humans the surface area of the stomach is less than one-third the size expected for a typical mammal of our body weight, and smaller than in 97 percent of other primates. The high caloric density of cooked food suggests that our stomachs can afford to be small. Great apes eat perhaps twice as much by weight per day as we do because their foods are packed with indigestible fiber (around 30 percent by weight, compared to 5 percent to 10 percent or less in human diets). Thanks to the high caloric density of cooked food, we have modest needs that are adequately served by our small stomachs.

Below the stomach, the human small intestine is only a little smaller than expected from the size of our bodies, reflecting that this organ is the main site of digestion and absorption, and humans have the same basal metabolic rate as other primates in relation to body weight. But the large intestine, or colon, is less than 60 percent of the mass that would be expected for a primate of our body weight. The colon is where our intestinal flora ferment plant fiber, producing fatty acids that are absorbed into the body and used for energy. That the colon is relatively small in humans means we cannot retain as much fiber as the great apes can and therefore cannot utilize plant fiber as effectively for

food. But that matters little. The high caloric density of cooked food means that normally we do not need the large fermenting potential that apes rely on.

Finally, the volume of the entire human gut, comprising stomach, small intestine, and large intestine, is also relatively small, less than in any other primate measured so far. The weight of our guts is estimated at about 60 percent of what is expected for a primate of our size: the human digestive system as a whole is much smaller than would be predicted on the basis of size relations in primates.

Our small mouths, teeth, and guts fit well with the softness, high caloric density, low fiber content, and high digestibility of cooked food. The reduction increases efficiency and saves us from wasting unnecessary metabolic costs on features whose only purpose would be to allow us to digest large amounts of high-fiber food. Mouths and teeth do not need to be large to chew soft, high-density food, and a reduction in the size of jaw muscles may help us produce the low forces appropriate to eating a cooked diet. The smaller scale may reduce tooth damage and subsequent disease. In the case of intestines, physical anthropologists Leslie Aiello and Peter Wheeler reported that compared to that of great apes, the reduction in human gut size saves humans at least 10 percent of daily energy expenditure: the more gut tissue in the body, the more energy must be spent on its metabolism. Thanks to cooking, very high-fiber food of a type eaten by great apes is no longer a useful part of our diet. The suite of changes in the human digestive system makes sense.

Could the tight fit between the design of our digestive systems and the nature of cooked food be deceptive? The character Pangloss in Voltaire's *Candide* claimed that our noses were designed to carry spectacles, based on the fact that our noses support spectacles efficiently. But actually spectacles have been designed to fit on noses, rather than the other way around. Following Pangloss's reasoning, in theory cooked food might similarly be well suited for a human gut that had been adapted for another kind of diet.

Meat is the obvious possibility. The "Man-the-Hunter" hypothesis assumes our ancestors were originally plant eaters, with the last species to eat relatively little meat being the australopithecine that gave rise to habilines more than two million years ago. Much of the australopithecines' plant food would have had the low caloric density and high fiber concentration seen in great-ape diets. We should therefore expect those ancient apes to have had large digestive systems, as chimpanzees and gorillas do today. In support of this idea, fossils show that australopithecines had broad hips and a rib cage that was flared outward toward the waist. Both features indicate the presence of capacious guts, held by the rib cage and supported by the pelvis. According to the meat-eating scenario, as increased amounts of meat were eaten by habilines and their descendants, modifications must have evolved in the mouth and digestive system.

Physical anthropologist Peter Ungar reported in 2004 that the molars (chewing teeth) of very early humans were

somewhat sharper than those of their australopithecine ancestors. They might therefore have been adapted to eating tough foods, including raw meat. Carnivores such as dogs, and probably wolves and hyenas, also tend to have small guts compared to those of great apes, including small colons that are efficient for the high caloric density and low fiber density of a meat diet. But despite these hints of humans being designed for meat eating, our mouths, teeth, and jaws are clearly not well adapted to eating meat unless it has been cooked. Raw wild meat from game animals is tough, which is partly why cooking is so important. Advocates of the meat-eating hypothesis have themselves noted that humans differ from carnivores by our having small mouths, weak jaws, and small teeth that cannot easily shear flesh.

The way food moves through our bodies compounds the problem. In carnivores, meat spends a long time in the stomach, allowing intense muscular contractions of the stomach walls to reduce raw meat to small particles that can be digested rapidly. Dogs tend to keep food in the stomach for two to four hours, and cats for five to six hours, before passing the food quickly through the small intestine. By contrast, humans resemble other primates in keeping food in our stomachs for a short time, generally one to two hours, and then passing it slowly through the small intestine. Lacking the carnivore system of retaining food for many hours in our stomachs, we humans are inefficient at processing chunks of raw meat.

If our mouths, teeth, jaws, and stomachs all indicate that humans are not adapted to eating lumps of raw meat, they might in theory be designed to digest meat that has been processed without being cooked. Raw meat might have been usefully pounded to make it easily chewed. It might have been allowed to rot, in parts of the world that were sufficiently cold for bacterial infection not to be a major threat. Or it might have been dried. But these ideas cannot solve the problem of how plant foods were eaten.

The problem is that tropical hunter-gatherers have to eat at least half of their diet in the form of plants, and the kinds of plant foods our hunter-gatherer ancestors would have relied on are not easily digested raw. So if the meat-eating hypothesis is advanced to explain why *Homo erectus* had small teeth and guts, it faces a difficulty with the plant component of the diet. It cannot explain how a human with a diminished capacity for digestion could have digested plant foods efficiently.

Plants are a vital food because humans need large amounts of either carbohydrates (from plant foods) or fat (found in a few animal foods). Without carbohydrates or fat, people depend on protein for their energy, and excessive protein induces a form of poisoning. Symptoms of protein poisoning include toxic levels of ammonia in the blood, damage to the liver and kidneys, dehydration, loss of appetite, and ultimately death. The grim result was described by Vilhjalmur Stefansson based on his experience in the

Arctic in a lean season when fat was so scarce (and plant foods were absent, as usual) that protein became the predominant macronutrient in the diet. "If you are transferred suddenly from a diet normal in fat to one consisting wholly of . . . [lean meat] you eat bigger and bigger meals for the first few days until at the end of about a week you are eating in pounds three or four times as much as you were at the beginning of the week. By that time you are showing both signs of starvation and protein poisoning. You eat numerous meals; you feel hungry at the end of each; you are in discomfort through distension of the stomach with much food and you begin to feel a vague restlessness. Diarrhoea will start in from a week to 10 days and will not be relieved unless you secure fat. Death will result after several weeks."

Because the maximum safe level of protein intake for humans is around 50 percent of total calories, the rest must come from fat, such as blubber, or carbohydrates, such as in fruits and roots. Fat is an excellent source of calories in high-latitude sites like the Arctic or Tierra del Fuego, where sea mammals have evolved thick layers of blubber to protect themselves from the cold. However, fat levels are much lower in the meat of tropical mammals, averaging around 4 percent, and high-fat tissues like marrow and brain are always in limited supply. The critical extra calories for our equatorial ancestors therefore must have come from plants, which are vital for all tropical hunter-gatherers. During periods of food shortage, such as the annual dry seasons, fat levels in meat would have been particularly low, down to 1 percent to

2 percent. A carbohydrate supply from plant foods would then have been especially vital.

But if early humans had the same small guts as we do, they could not have obtained their plant carbohydrates without cooking. Recall the poor metabolic performance of the urban raw-foodists in the Giessen study. Those people ate very high-quality cultivated food processed with the aid of sprouting, blending, and even low-temperature ovens, yet still obtained so little energy that reproductive function was seriously impaired. If our early human ancestors indeed ate their plant food raw, they would have needed to find ways of processing it that were superior to our modern technology. But it is not credible that Stone Age people developed non-thermal methods of food preparation more effective than using an electric blender.

Hunter-gatherers living on raw food might sometimes have found plant foods of an exceptionally high caloric density, such as avocados, olives, or walnuts. But no modern habitats produce such foods in abundance all year. Perhaps a few lost places would have had highly productive natural orchards until they were replaced by agriculture, such as the fertile valleys of the Middle East. But occasional productive areas would not explain the wide geographical range of human ancestors across Africa, Europe, and Asia by 1.8 million years ago. Furthermore, seasonal scarcities occur in every habitat and would have forced people to use foods of lower caloric density, such as roots. The notion of a permanently superproductive habitat is unrealistic. People with an

anatomy like ours today could not have flourished on raw food in the Pleistocene epoch.

Beyond reducing the size of teeth and guts, the adoption of cooking must have had numerous effects on our digestive system because it changed the chemistry of our food. Cooking would have created some toxins, reduced others, and probably favored adjustments to our digestive enzymes. Very little is known about how our detoxification system and enzyme chemistry differ from those of great apes, but studies should eventually provide further tests of the hypothesis that human bodies are adapted to eating cooked foods.

Take, for example, Maillard compounds, such as heterocyclic amines and acrylamide. These complex molecules are formed from a process that begins with the union of sugars and amino acids, particularly lysine. Maillard compounds occur naturally in our bodies and increase in frequency with age. They occur at low concentration in natural foods but under the influence of heat their concentration becomes much higher than what is found in nature, whether in smoke (from fires or cigarettes) or cooked items. Their presence is easily recognized in the brown colors found in pork crackling or bread crust. Maillard compounds cause mutations in bacteria and are suspected of leading to some human cancers. They can also induce a chronic state of inflammation, a process that raw-foodists invoke to explain why they feel better on raw diets. The cooking hypothesis

suggests that our long evolutionary history of exposure to Maillard compounds has led humans to be more resistant to their damaging effects than other mammals are. It is an important question because many processed foods contain Maillard compounds that are known to cause cancer in other animals. Acrylamide is an example. In 2002 acrylamide was discovered to occur widely in commercially produced potato products, such as potato chips. If it is as carcinogenic to humans as it is to other animals, it is dangerous. If not, it may provide evidence of human adaptation to Maillard compounds, and hence of a long exposure to heated foods.

Evolutionary adaptation to cooking might likewise explain why humans seem less prepared to tolerate toxins than do other apes. In my experience of sampling many wild foods eaten by primates, items eaten by chimpanzees in the wild taste better than foods eaten by monkeys. Even so, some of the fruits, seeds, and leaves that chimpanzees select taste so foul that I can barely swallow them. The tastes are strong and rich, excellent indicators of the presence of non-nutritional compounds, many of which are likely to be toxic to humans—but presumably much less so to chimpanzees.

Consider the plum-size fruit of *Warburgia ugandensis*, a tree famous for its medicinal bark. *Warburgia* fruits contain a spicy compound reminiscent of a mustard oil. The hot taste renders even a single fruit impossibly unpleasant for humans to ingest. But chimpanzees can eat a pile of these fruits and then look eagerly for more.

Many other fruits in the chimpanzee diet are almost equally unpleasant to the human palate. Astringency, the drying sensation produced by tannins and a few other compounds, is common in fruits eaten by chimpanzees. Astringency is caused by the presence of tannins, which bind to proteins and cause them to precipitate. Our mouths are normally lubricated by mucoproteins in our saliva, but because a high density of tannins precipitates those proteins, it leaves our tongues and mouths dry: hence the “furry” sensation in our mouths after eating an unripe apple or drinking a tannin-rich wine. One has the same experience when tasting chimpanzee fruits such as *Mimusops bagshawei* or the widespread *Pseudospondias microcarpa*. Though chimpanzees can eat more than 1 kilogram (2.2 pounds) of such fruits during an hour or more of continuous chewing, we cannot. Some other chimpanzee foods taste bitter to us, such as certain figs. Still other fruits elicit in us unusual sensations, such as the fruits of *Monodora myristica*, whose sharp and lemony taste is followed by a numbing sensation at the tip of the tongue like that caused by novocaine. Of the scores of chimpanzee foods I have tasted, I could imagine filling my belly with only a very few species, such as a wild raspberry—but alas, one rarely finds more than a handful of these delicious fruits at a time. The shifts in food preference between chimpanzees and humans suggest that our species has a reduced physiological tolerance for foods high in toxins or tannins. Since cooking predictably destroys many toxins, we may have evolved a relatively sensitive palate.

By contrast, if we were adapted to a raw-meat diet we would expect to see evidence of resistance to the toxins produced by bacteria that live on meat. No such evidence is known. Even when we cook our meat we are vulnerable to bacterial infections. The U.S. Centers for Disease Control and Prevention state that at least forty thousand cases of food poisoning by *Salmonella* alone are reported annually in the United States, and as many as one million cases may go unreported. The estimated total number of cases due to the top twenty harmful bacteria, including *Staphylococcus*, *Clostridium*, *Campylobacter*, *Listeria*, *Vibrio*, *Bacillus*, and *Escherichia coli* (*E. coli*), is in the tens of millions per year. The best prevention is to cook meat, fish, and eggs beyond 140°F (60°C), and not to eat foods containing unpasteurized milk or eggs. The cooking hypothesis suggests that because our ancestors have typically been able to cook their meat, humans have remained vulnerable to bacteria that live on raw meat.

Anthropology has traditionally adopted the Man-the-Hunter scenario, proposing our species as a creature that was modified from australopithecines principally by our tendency to eat more meat. Certainly meat eating has been an important factor in human evolution and nutrition, but it has had less impact on our bodies than cooked food. We fare poorly on raw diets, no cultures rely on them, and adaptations in our bodies explain why we cannot easily utilize raw foods. Even vegetarians thrive on cooked diets. We are cooks more than carnivores. No wonder raw-foodism is a good way to lose weight.